Polarization Studies Group Newsletter

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News from Advanced Photon Source Sector 4

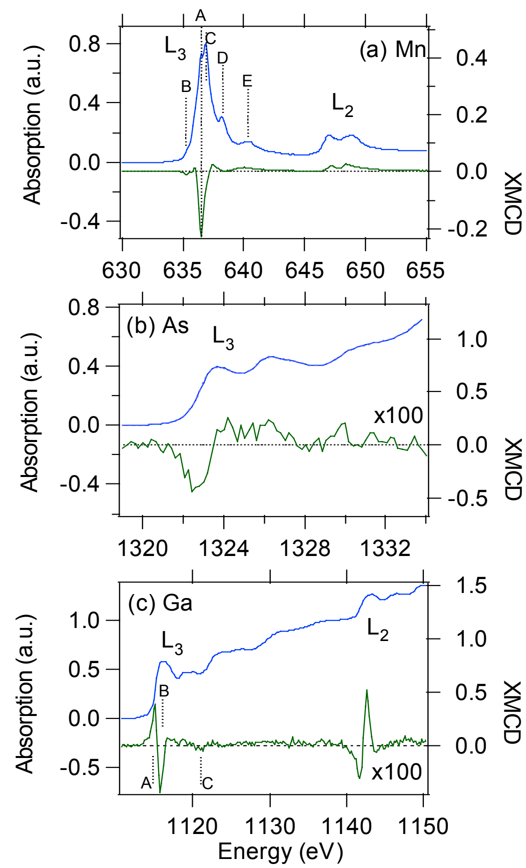
Application deadline for beamtime is August 1 for Sep.-Dec. cycle in 2003. If your are interested in applying for beamtime, or developing a collaboration with sector 4 staff, visit Advanced Photon Source website www.aps.anl.gov, or contact Polarization Studies Group leader, George Srajer, at srajerg@aps.anl.gov.

Research Highlights

In this issue we present results of two experiments both of which take full advantage of in-line polarization capabilities available on sector 4 beamlines. First, a soft x-ray dichroism experiment done on 4-ID-C provides the first unambiguous evidence for induced moments of As and Ga 4s bands in dilute ferromagnetic semiconductors. The second experiment, performed on hard x-ray branch line 4-ID-D, provides a real-space image of magnetic spiral domains in holmium metal by utilizing the sensitivity of circular polarization in resonant scattering to domain chirality.

Element-resolved spin configuration in ferromagnetic Mn-doped GaAs

(Contact: David Keavney, keavney@aps.anl.gov)



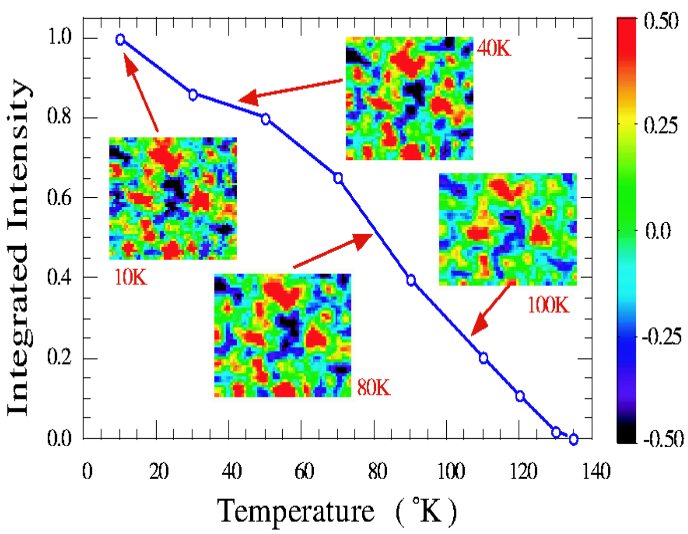
Semiconductors doped with magnetic ions, such as (Ga,Mn)As, are of great interest because they allow the combination of semiconducting band structure and ferromagnetism. However, the origins of ferromagnetic ordering in such materials are not fully understood. It is generally thought that Mn ions go primarily into Ga sites, and that coupling between them is mediated by spin polarized holes derived from the neighboring As atoms. This model predicts that As should have a small magnetic moment aligned antiparallel to the Mn ions, while Ga should have an even smaller, but, parallel moment.

X-ray magnetic circular dichroism (XMCD) offers powerful insight into the coupling mechanism by revealing the GaAs host moments with element specificity. We have used the 4-ID-C soft x-ray beamline to examine induced moments in (Ga,Mn)As via XMCD at the Mn, Ga, and As *L* edges. The figure on the right shows soft x-ray absorption (blue curves) and XMCD (green curves) profiles through the Mn, As, and Ga *L* edges, respectively, for $Ga_{0.93}Mn_{0.07}As$. We find dichroism signals at all three edges, indicating small induced moments on the As and Ga 4*s* bands. These induced moments are present across a broad range of Mn doping, and scale with the Mn dichroism signal. The signs of the XMCD signals show that the As induced moments are antiparallel to the Mn, while the Ga is parallel, consistent with recent predictions. The induced moments show identical hysteresis loops and temperature dependence as the Mn, clearly associating them with the ferromagnetic semiconductor phase of (Ga,Mn)As.

Imaging chiral magnetic domains in holmium

(Contact: Jonathan C. Lang, lang@aps.anl.gov)

Recently on beamline 4-ID-D we have used circularly polarized x-rays to image the chirality of magnetic domains in a holmium (Ho) single crystal for the first time. At low temperature Ho moments form spiral magnetic structures, where the magnetization direction rotates between successive atomic layers forming a helix along the **c**-axis. This magnetic superstructure results in magnetic satellites on either side of charge Bragg peaks at $(0,0,L\pm\tau)$ where τ is the inverse of the periodicity of magnetic spirals. At these magnetic peaks, circularly polarized x-rays are sensitive to the handedness of such a helix (*i.e.* either right or left handed). By reversing the incident-beam helicity and measuring the difference in the Bragg scattering for different photon polarizations, contrast between magnetic domains of opposing handedness can be obtained. Near the Ho L_3 absorption edge magnetic scattering from Ho is strongly enhanced. Likewise the contrast varies dramatically from ~-10%, away from the edge, to ~80% at the resonantly enhanced peak.



The figure on the left plots the intensity of the $(0,0,4+\tau)$ magnetic peak along with a series of 600 μm×450 μm domain images taken for different temperatures. The images were obtained using a $25x25\mu m^2$ incident beam. The Ho crystal was placed inside closed-cycle helium refrigerator, mounted to a Huber ψ-circle goniometer. The sample was oriented to excite a magnetic Bragg peak and the goniometer and sample were scanned through the beam, reversing the helicity at each point in the raster. The domain structure in these images appears to be frozen in, with very little changes seen with increasing temperature. Warming the sample past T_N and recooling, resulted in a completely different domain pattern indicating that pinning centers such as crystalline defects, impurities, etc. play no significant roles in the nucleation of spiral domains. Future experiments to image domains near phase-transition temperature are planned.